THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

British Gas Turbines: Historical Review

'The Story of the British Gas Turbine. A Festival Survey.' Published by Power Jets (Research and Development), Ltd., 1951; 40 pp.

The object of this brochure is 'to tell the story of British gas-turbine development, to sketch the broad outline of existing work now being carried out in this country, and to indicate plans for the future.' It is intended to bring useful information to a wide range of readers, including those who, while possessing a measure of general engineering knowledge, may not fully appreciate the basic ideas underlying the gas turbine, and the methods by which the power it produces can be applied for the propulsion of ships, aircraft, locomotives and road vehicles, for the production of electricity, and for other processes and duties which are at present only partially developed.

The opening section of the brochure gives a simple description of the fundamental principles of the gas turbine, its operation, and its advantages as a means of power generation. This is followed by a historical review, including reference to developments in other countries, as a background to a more detailed survey of British activities. The story of close collaboration between the British Government, scientific establishments and industrial firms is well portrayed, indicating the essential inter-relationship of research and development, without which the progress made could not have been achieved. In connexion with the importance of metallurgical research, attention is directed to the work of the many firms who were responsible for evolution of materials which would withstand the severe conditions obtaining in gas-turbine operation. The Nimonic alloys, R.ex 78, H.R. Crown Max, the 326 and 337 steels, G. 18B, and ferritic steels of the H.40 and other types are mentioned as typical of the materials which made so indispensable a contribution to progress in this field. Materials developed for heat exchangers were a further feature of metallurgical interest; some account of these is given. A note is added on the units developed for fuel supply and control in the turbines.

A later section of the publication records the contributions of firms who have undertaken manufacture of gas turbines and have carried out much research and development in this connexion. Progress made, and some of the major units produced by the respective makers, are briefly described and illustrated, with notes on the general industrial importance of such developments.

The contribution of Power Jets, Sir Frank Whittle's original company, is indicated, and the part which the British Government research establishments have played and their rôle in future development are considered. The nature of the work in hand by the respective Departments is briefly recorded.

Review of progress to date justifies the conclusion that British technology in relation to the gas turbine is internationally recognized and that continuance of co-ordinated research and development will ensure maintenance of a high level of achievement in the future.

Within the limits inherent in a brochure of this size and scope, the material presented gives a comprehensive idea of progress in this relatively new, but, important, field of power production.

Production of Fine Wire by Electropolishing

See abstract on p. 184.

Nickel-containing Materials in British Coinage

See abstract on p. 175.

NICKEL

Influence of Composition of Cathode Nickel on Thermionic Properties and Life

H. E. KERN and R. T. LYNCH: 'Initial Emission and Life of a Planar-type Diode as Related to the Effective Reducing Agent Content of the Cathode Nickel.' *Physical Rev.*, 1951, vol. 82, May 15, p. 574; Abs. E.P. 10.

Abs. of paper to Amer. Physical Soc., Jan. 1951.

'A description of the Bell Laboratories planar-type diode is given, as well as a brief outline of the method of determining cathode emission and the conditions of life testing the diode. A method is described for calculating the effective reducing-agent content of a cathode nickel based on the following factors: (1) the chemical composition of the nickel; (2) the equations of the chemical reactions between the reducing agents in the nickel and the oxide coating; (3) the thickness of the nickel directly beneath the oxide coating. A correlation is shown to exist between this effective reducing-agent figure and both initial cathode emission and tube life. In general, as the effective reducing-agent content of the nickel is increased the initial emission also increases, but not without limit. Increase of the reducing-agent content above a certain level causes no further increase in initial emission. The relationship between tube life and effective reducing-agent content indicates that a maximum tube life is obtained over a very narrow range of effective reducing-agent values and that this maximum is apparently limited to a region in which the effective reducing-agent content is approximately chemically equivalent to the total oxide-coating content.'

Ferro-Magnetic Resonance in Metal Films

J. H. E. GRIFFITHS: 'Ferro-Magnetic Resonance in Thin Ni-Films.' *Physica*, 1951, vol. 17, Mar.-Apr., pp. 253-8.

The paper reports observations made on films of nickel, 0·1-3 μ thick, prepared by evaporation onto mica. The value of magnetic field for which the absorption was a maximum appeared to be dependent on the thickness of the film. The results are interpreted in terms of Kittel's equation which involves the quantity $(N_y-N_z)I$, where N_y and N_z are the demagnetizing factors normal to the plane of the film and in the direction of the static magnetic field, respectively, and I is the saturation intensity of magnetization.

A new oscillation type of magnetometer is described, by which both I and (N_y-N_z) may be measured. Results of these measurements, combined with the ferromagnetic resonance measurements on the same samples, show that the g value for nickel is independent of thickness and that the change in resonance magnetic field is, in nearly all cases, due to a change in (N_y-N_z). This is interpreted as arising from strain in the nickel film, due to differential contraction of the nickel and the mica substrate on cooling from the annealing temperature. Calculations show that this should give a change of the right order of magnitude. Other experiments described support this view.

Diffusion of Magnesium Through Nickel

G. F. ROUSE and R. FORMAN: 'Diffusion of Magnesium through Nickel.' *Physical Rev.*, 1951, vol. 82, May 15, p. 574; Abs. E.P. 9.

Abs. of paper to Amer. Physical Soc., Jan., 1951.

'By means of an evaporation apparatus, operating under very good vacuum conditions, a magnesium-nickel system is formed consisting of a thin layer of magnesium sandwiched between a relatively thick sheet of pure electrolytic nickel and a much thinner layer of the same nickel. When this system is held at a temperature above the melting point of magnesium the magnesium diffuses through the thin nickel layer and evaporates from its surface. Thus, a zero magnesium concentration is maintained at the surface. This behaviour, together with the known initial concentration - distribution of magnesium, makes it possible to describe the process mathematically, with diffusion constant as a parameter. The fractional amount of magnesium evaporated and the corresponding time appear in the equation and are measurable quantities. Properly distributed experimental values of these latter quantities make it possible to establish a value for the diffusion constant. Preliminary data indicate that the diffusion constant for a temperature of 720°C. is greater than 10^{-9}cm²/sec. Steps to acquire sufficient data to fix the value of the constant more exactly are under way.'

Determination of Nickel in Manganese Bronze

See abstract on p. 175.

Spinning on Automatic Lathes

See abstract on p. 183.

Spectrophotometric Estimation of Nickel in Aluminium Alloys

M. D. COOPER: 'Spectrophotometric Determination of Nickel in Aluminum Alloys.' *Analytical Chemistry*, 1951, vol. 23, June, pp. 880-3.

The procedure described for decomposing the sample and for preparation of the sample solution are similar to those recommended in 'Methods of Chemical Analysis of Metals', published by the American Society for Testing Materials. The work reported was undertaken to test the applicability of the method for determination of nickel in aluminium-base materials.

Procedure to the stage of production of the sample solution is identical for all grades of alloy: subsequent procedure is governed by the method selected for overcoming interference by copper. Procedure is detailed for removal of copper as sulphide, or by electrolysis, and a third method of procedure provides for determination of nickel in presence of copper. Preliminary removal of copper is essential where a high degree of accuracy is required, but the method which dispenses with copper removal is considered to give a degree of precision satisfactory for routine analysis. Typical data show results obtainable by the three procedures.

With regard to the relative advantages of the various methods the following comments are made:—'Aside from the obvious evils of hydrogen sulphide, the method in which copper is removed by electrolysis has the advantage from the standpoint of the time required for a determination (45 minutes compared with 55-60 minutes required in the sulphide method). By the routine method without removal of copper, about 30 samples can be analyzed in 15 hours.'

Spectrophotometric Estimation of Nickel in Steel

M. D. COOPER: 'Spectrophotometric Determination of Nickel in Steel.' *Analytical Chemistry*, 1951, vol. 23, June, pp. 875-80.

The method described is essentially a modification of that proposed by HAYWOOD and WOOD (*Metallurgical Analysis*, published by Adam Hilger, Ltd., London, 1944, see p. 64). The reagents used are closely similar, but the order of their addition has been changed, with resulting improvement in stability. Specifically, the method is characterized by oxidation of nickel in presence of dimethylglyoxime, the iodine solution being added to the ammoniacal solution of the sample. The absorbency of the nickel compound, when formed in the absence of other metallic elements, reaches a maximum within two or three minutes, and remains constant for at least 25 minutes.

The work reported has established the nature and degree of interference of copper and manganese: the range of ratios of these two elements to nickel which can be tolerated is evaluated, and methods for correction of interference are suggested. Although cobalt is usually of little significance in analysis of low-alloy steels, attention is directed to the fact that this element, when it is present, interferes seriously. A modified procedure, providing for determining of nickel in cobalt-base materials, such as certain high-temperature materials, is to be published later.

Analytical results obtained by the newly modified spectrophotometric procedure (recorded on standard samples, in comparison with determinations made by the gravimetric dimethylglyoxime method) show it to be preferable, from the dual standpoint of accuracy and speed. It is also demonstrated as more satisfactory than the cyanide-titration method. Full details of recommended procedure are given.

Determination of Nickel in Plants

L. E. REICHEN: 'Geochemical Field Method for Determination of Nickel in Plants.' *Analytical Chemistry*, 1951, vol. 23, May, pp. 727-9.

The use of information on the chemical composition of plants as a means of prospecting for ore bodies has made apparent the need for quick methods of analysis for plants which may contain traces of metallic constituents. Investigations reported by various authors have shown that plants normally contain small amounts of nickel; the paper opens with a useful documented review of the literature on nickel content of plants and soils.

The pertinent features of the field test described are the elimination of the customary drying and controlled-ashing procedures. The fresh vegetation is ashed directly over a flame, the ash is put into solution with hydrochloric acid, the solution is buffered with sodium citrate, and pH is adjusted to 8·8 with ammonium hydroxide. Standard solutions of increasing nickel concentration are passed through a reagent paper impregnated with dimethylglyoxime, to give a series of confined spots, and nickel concentration is estimated by the intensity of the pink coloration produced. Spots from the sample solutions are compared with a standard series of spots, to determine the amount of nickel present.

It is claimed that as little as 0·025 per cent. nickel in plant ash can be determined, and that by a simple modification of procedure, traces as low as 0·003 per cent. can be detected. The accuracy of the method is demonstrated by comparison with analyses made by standard laboratory procedure. The method has the added advantage of speed: it is possible for an experienced analyst to make 30 determinations in an 8-hour working day.

Chemical Reactions of Nickel Carbonyl

I. D. WEBB and G. T. BORCHERDT: 'Coupling of Allylic Halides by Nickel Carbonyl.' *Jnl. Amer. Chemical Soc.*, 1951, vol. 73, June, pp. 2654-5.

Representative allylic chlorides can be coupled, in excellent yields, by using nickel carbonyl in methanol as solvent. The diene hydrocarbons produced are richer in straight-chain (terminally coupled) product than those generally produced by metal-coupling reactions, but isomeric allylic chlorides yield identical mixtures of isomeric dienes. The experimental facts recorded indicate that the mechanism of the nickel-carbonyl coupling reaction may involve free allyl or substituted allyl radicals.

A note is added on precautions necessary in handling nickel carbonyl.

ELECTRODEPOSITION AND OTHER COATING METHODS

Optimum Use of Nickel in Plating: Practical Recommendations

'Choose the Right Nickel Plating System.' *Steel*, 1951, vol. 128, June 4, pp. 94-6, 117-18, 121, 124, 127, 130, 132.

Limitations placed, both in Britain and America, on the use of nickel for plating, and the current shortage of supplies for this purpose, emphasize the need for close control of operating conditions, in order to secure best results with maximum economy.

This article makes a practical contribution to the needs of the plater, giving detailed recommendations on baths and technique of plating. Some of the more important points are extracted below.

Solutions.

The *Watts type of bath* offers a good degree of flexibility, with regard to composition, current density and temperature. Two types are in use:

	High-pH Type	Low-pH Type
	oz./gal.	oz./gal.
Nickel sulphate ..	32	44
Nickel chloride ..	6	6
Boric acid	4	5
pH	4·5-6·0	1·5-4·5
Temperature	115°-160°F. (46°-71°C.)	115°-140°F. (46°-60°C.)
Current density ..	20-100 amp./sq. ft.	25-100 amp./sq. ft.

The following are considered to be the advantages of the low-pH solution:

(1) Higher current densities can be employed without danger of peeling and cracking of the deposit, thus increasing the output per tank.

(2) With most types of anode, depending on the particular combination of pH, chloride concentration, and current density, improved anode efficiency is obtained, and the bath is operated more economically, due to resultant decrease in nickel-salt consumption.

The disadvantages of the low-pH bath are:

(1) Lower throwing power at low current densities.

(2) Tendency to pitting at some points in the pH range.

(3) Lower cathode efficiency.

Typical properties of deposits made from the low-pH Watts bath are Vickers hardness 140-160; tensile strength 51,000 p.s.i. (23 tons per sq. in.); elongation 30 per cent. in 2 in. The deposits are ductile, and steel parts plated from this solution can be drawn and fabricated with ease.

A typical *all-chloride bath* contains 40 oz./gall. of nickel chloride, with 4 oz./gall. of boric acid. It is operated at pH of 2·0, at 140°F. (60°C.). Deposits from such solutions are finer-grained, harder, smoother, stronger and less ductile than those made from the Watts bath. Typical values are: hardness 230-260; tensile strength 98,900 p.s.i. (44 tons per sq. in.); elongation 21 per cent. in 2 in. This solution permits a lower voltage, and has a wide plating range: other

advantages are a reduced tendency to pitting and treeing, and production of a smooth, tough deposit which is easily buffed. It is also easy to control. Its chief disadvantage is the corrosive effect of the high chloride content, which presents a practical problem with regard to equipment.

The intermediate-type *chloride-sulphate bath* is typically of the following composition:

	oz./gal.
Nickel sulphate	26
Nickel chloride	23
Boric acid	5·3

pH is 1·5, and it is used at 115°F. (46°C.), with a current density of 100 amp./sq. ft.

The increased chloride content, by comparison with the Watts solution, ensures a smoother, finer-grained, and more easily buffed deposit, with less tendency to pit, and the bath has the added advantage that it can be operated at lower tank voltages and higher current densities at greater current efficiencies. By comparison with the all-chloride solution, the chloride-sulphate bath gives a more ductile deposit, and provides easier control and purification; it also has wider possibilities with regard to addition of organic brighteners. This solution again presents some problems with regard to corrosive attack on equipment. Lead cannot be used, but Karbate heaters and rubber-lined tanks are satisfactory.

Nickel has some advantages over chromium in certain cases where a deposit of medium hardness is required for building-up purposes. It is tougher, more easily machinable, and, in many cases, more resistant to corrosion. It can also be deposited at a higher rate than chromium and gives better distribution over irregular objects.

A bath recommended for *hard nickel plating*, and the properties of the deposits obtained from it, are shown below:

	oz./gal.
Nickel sulphate	24
Ammonium chloride	3·3
Boric acid	4·0
pH	5·6-5·9
Temperature	110°-140°F. (43°-60°C.)

From such baths deposits showing a Vickers hardness of 425, tensile strength of the order of 152,000 p.s.i. (68 tons per sq. in.) and an elongation of 6 per cent. in 2 in. are obtained. Variation of pH and temperature can be used to develop hardnesses over a relatively wide range.

In *barrel plating*, the following solution is satisfactory for production of a matte deposit:

	oz./gal.
Nickel sulphate	20
Ammonium chloride	4
Boric acid	4
pH	5·0-5·5
Room temperature	

Current density is difficult to specify in a general manner, due to the nature of barrel plating and the movement of the work. It is recommended that the barrels used should have the largest possible openings compatible with retention of the work, and that care be taken to prevent 'nesting'. Good electrical connection must be ensured.

Certain *special-purpose baths* for nickel plating are also specified in this article, e.g.,

For plating on interior parts not subject to corrosive conditions a cold bath of the following composition is suggested.

	oz./gal.
Nickel sulphate	16
Ammonium chloride	2
Boric acid	2
pH	5·0-5·5
Room temperature	
Current density	5-10 amp./sq. ft.

A brightening agent, such as gum tragacanth, gum arabic, or cadmium is usually added.

In connexion with the use of nickel deposits for building up and reinforcement purposes, attention is directed to the importance of adequate cleaning of the basis material before plating. The surface to be plated should have a smooth finish (best results are obtained on finely machined, ground, or sand-blasted surfaces), and after degreasing should be subjected to the following preparatory operations: pumice scrub and water rinse; cathodic treatment for 2 minutes in alkaline electrolytic cleaner; pumice scrub and water rinse; second alkaline cathodic treatment, for ½ minute; water rinse. This cycle is followed by an acid pickle, selected according to the material to be plated.

In handling heavy work care must be taken to determine the best location for thieves and auxiliary anodes, spacing of tanks, etc. Some practical recommendations for typical cases are made.

Even under ideal conditions, anode bags and continuous filtration must be regarded as essential in plating heavy deposits; it is suggested that, as a general rule, a volume of solution equal to that of the whole tank should pass through the filter every hour. It is of primary importance to avoid interruption of plating, which will cause laminations in the deposit. If such interruption does occur the current should be switched off, and the parts removed from the tank, cleaned, stripped, and rinsed before re-plating. Specific recommendations are made with regard to plating conditions suitable for treatment of rolls.

The following table indicates the effect of temperature on nickel deposits of various initial hardnesses, indicating both the treatments which may be used to decrease hardness and increase ductility, and the limiting working temperatures to which nickel deposits can safely be exposed.

Initial Hardness (Vickers)	Time, hrs.	Temperature °F.	Temperature °C.	Final Hardness (Vickers)
325	18	400	205	295
325	1 week	400	205	295
325	18	500	260	295
470	24	500	260	400-450
475	4	600	315	222
445	4	600	315	380

With regard to finishing, shaping or planing is not recommended, but milling is suitable. Cutting tools of the cast non-ferrous or cemented-carbide type may be used and a mixture of soluble oil and water should be used as coolant. Suggested cutting speeds are 80 and 120-175 f.p.m. respectively, for the two types of tool. Feed for both types should be of the order of 0·008 for finish cuts and 0·010-0·015 for roughing cuts.

Plating of Stainless Steels

J. HAAS: 'Electroplating Stainless Steels. A Critical Review with Recommended Practices.' *Metal Finishing*, 1951, vol. 49, June, pp. 50-4.

The article is introduced by reference to the early history of the commercial use of stainless steel in industries in which the question of electroplating could arise (tableware, fountain pens, and domestic utensils). This is followed by a note on the nature of the passivity of these steels, which introduces difficulties in obtaining satisfactory adhesion of electrodeposited coatings; the deleterious influence of hydrogen when adsorbed during pickling is also discussed.

The greater part of the article comprises a review of some major technical and patent literature on plating of stainless steel, and a schedule of recommended procedure, based on the writer's own experience, as well as on published information. This schedule and the related chart are reproduced below.

Recommended Practices for Plating Stainless Steel

Method	Operation												
	6	7	8	9	10	11	12	13	14	15	16	17	18
1 ..	×	×	×	×	×							×	×
2 ..	×	×	×	×	×	×	×					×	×
3 ..	×	×	×	×	×	×		×	×			×	×
4 ..	×	×	×	×	×	×		×		×		×	×
5 ..	×	×	×	×	×	×					×	×	×
6 ..	×		×	×	×							×	×
7 ..	×		×	×	×	×	×					×	×
8 ..	×		×	×	×	×		×	×			×	×
9 ..	×		×	×	×	×		×		×		×	×
10 ..	×		×	×	×	×					×	×	×
11 ..		×	×	×	×							×	×
12 ..		×	×	×	×	×	×					×	×
13 ..		×	×	×	×	×		×	×			×	×
14 ..		×	×	×	×	×		×		×		×	×
15 ..		×	×	×	×	×					×	×	×
16 ..		×	×				×					×	×
17 ..		×	×					×	×			×	×
18 ..		×	×					×		×		×	×
19 ..	×		×				×					×	×
22 ..	×		×								×	×	×
23 ..	×										×	×	×
24 ..											×	×	×

'Operation Details

1. Stainless steel pre-cleaned with trichlorethylene degreaser, or any other satisfactory method.
2. Electro-clean: 180°-190°F. (82°-88°C.); 6 volts.
   (*a*) Direct—30 secs.
   (*b*) Reverse—30 secs.
   (*c*) Direct—30 secs.
3. Water rinse.
4. Acid dip.
   Fluoboric acid (25%) 30 secs.
   or
   Hydrochloric acid (25%) 30 secs.
5. Water rinse.

From this stage treatment is optional: the writer prefers the hydrochloric acid/electro-activator method, as the most reliable and as producing the most uniform and successful results.

6. Electro-Activator solution: 70°F. (21°C.); 6 volts; carbon anodes—
   (*a*) Hydrochloric acid (50%) 2 mins. *or*
   (*b*) Sulphuric acid (10%) 2 mins.
7. Nickel strike solution: 70°F. (21°C.); 3-4 volts; 2 mins.; nickel anodes—
   Nickel chloride .. 32 oz./gal.
   Hydrochloric acid .. 16 fl. oz./gal.
8. Water rinse.
9. Rinse: Nickel sulphate solution, 32 oz./gal.; pH 5·6.
10. Nickel plate: 70°-110°F. (21°-43°C.); 1·75-2 volts; 10 mins.
    Nickel sulphate .. 24 oz./gal.
    Nickel chloride .. 8 oz./gal.
    Boric acid .. 2·5 oz./gal.
    pH .. 5·6-5·8
11. Water rinse.
12. Acid Copper: 70°F. (21°C.); 0·5-0·75 volts; 30 mins.
    Copper sulphate .. 32 oz./gal.
    Sulphuric acid .. 8 fl. oz./gal.
13. Electro Cyanide (6 oz./gal.), 110°F. (43°C.); 15 secs.
14. Cyanide Brass (Standard brass) pH 12·2; 10-20 mins.
15. Cyanide (Dupont H.S.) Copper, pH 11·2-11·8.
16. Chromium solution: Standard solution; standard operating conditions; 2-3 mins.
17. Water rinse.
18. Hot-water dry.'

Additional notes are given on the importance of adequate rinsing and on the surface conditioning of stainless steels prior to plating. A rinse in a solution similar to the plating bath is specially recommended.

Sulphuric acid as an activator is not recommended in concentrations above 10 per cent., due to undesirable action on the steel.

The following notes relate to recommendations specific to methods mentioned in the chart.

'*Method* 20. After operation No. 8, immerse in sodium cyanide solution, 8 oz./gal. at 110°F. (43°C.); transfer to Rochelle copper strike solution; 15-20 secs., cathode agitation, at 2½-3 volts; rinse and place in brass solution. Operate brass solution at 1·75-2·00 volts with cathodic agitation.'

'*Method* 21. After operation No. 8, immerse in sodium cyanide solution, 8 oz./gal. at 110°F. (43°C.); transfer to Rochelle copper strike solution; 15-20 secs., cathode agitation, at 2½-3 volts; rinse and place in high-speed copper solution. Operate at 1·00-1·25 volts with cathodic agitation. Silver may be plated on stainless steels, substituting the silver strike for the copper strike.'

'*Method* 23. No electric current used in operation No. 6; merely two minutes' agitated immersion.'

'*Method* 24. Chromium plating on stainless steels directly presents no problem, because the chromium solution is itself an activating solution.'

Preferred Orientation in Nickel Deposits on Single Crystals

H. LEIDHEISER and A. T. GWATHMEY: 'Bright Nickel Plating on Metallic Single Crystals in the Absence of Addition Agent.' *Jnl. Electrochemical Soc.*, 1951, vol. 98, June, pp. 225-30.

It is known that bright plating of metals is often accompanied by a preferred orientation of the deposit.

Property of Deposit	(100)	(111)
Surface appearance	Smooth and mirror-bright	Matte and rough
Crystallinity	Single crystal	Polycrystalline
Current density	Same on both faces	Same on both faces
Current efficiency	Same on both faces	Same on both faces
Hardness	Soft	Harder than (100)
Ductility	Excellent	Less than (100)
Porosity	Compact plate	Comparatively porous
*Corrosion resistance	Excellent	Comparatively poor

* The following corroding conditions were used: (1) 10% hydrochloric acid, action of alternating current in the Watts-type bath, and (2) electrolytic etching in nitric acid-acetic acid solution.

This paper reports an outstanding example of the phenomenon, and describes observations which, it is considered, assist in formulating a theory of the mechanism of bright plating.

Nickel was electrodeposited, from a Watts-type bath, on electrolytically polished single-crystal spheres of copper and nickel, under a wide variety of plating conditions. Two major effects were observed: (1) the deposit which formed on the (100) faces and on faces making a small angle with the (100) plane remained mirror-bright to thicknesses as great as 0·01 in.; the deposits on the (111) faces and on faces making a small angle with the (111) plane became matte from the start of deposition.

X-ray examination, at grazing incidence, indicated that the deposit on the (100) face remained monocrystalline, whereas that on the (111) face was polycrystalline from the start. Under the experimental conditions used, the polycrystalline deposit rapidly assumed a (100) preferred orientation. The properties of the electrodeposits formed on the (100) and the (111) faces are compared in the table above.

Determination of Thickness of Nickel Coatings on Zinc-base Die Castings

H. E. BROWN: 'Determination of Plate Thickness on Zinc base Alloy Die-Castings.' *Plating*, 1951, vol. 38, June, pp. 556-7.

The method described is designed to give average thickness on significant surfaces.

Chromium Plating. Total significant area is calculated from measurement of dimensions, and non-significant areas are blocked off with rubber and/or beeswax. The plating is dissolved in 20 per cent. by vol. solution of concentrated hydrochloric acid, and weight of chromium is determined by converting $CrCl_3$ to CrO_3 with perchloric acid, and titration of the CrO_3 with ferrous ammonium sulphate and potassium permanganate. The beeswax coating is removed by immersion in boiling water.

Nickel and Copper Coatings. The zinc-alloy base is dissolved by immersion in beakers containing 200 ml. of 20 per cent. by vol. concentrated hydrochloric acid and 3 ml. additional concentrated acid for each gram of alloy. After the base is completely dissolved away (about 26 hours' immersion) the copper and nickel shells are removed and non-significant portions are broken off. Each shell is tested for undissolved zinc by immersing it in a solution of 50 vol. per cent. hydrochloric acid. When free of zinc, the shell is rinsed, first in running water and afterwards in distilled water, dipped in alcohol, dried in an air bath, cooled, and weighed. The result is the combined weight of nickel and copper plating.

Removal of Copper from Nickel. Two alternative methods: (1) polysulphide-cyanide; (2) chromic-sulphuric acid. The second is the more generally useful.

(1) The polysulphide solution is made from sodium sulphide 20 g., sulphur 20 g., water 1 litre. The cyanide solution is a 20 per cent. solution of sodium cyanide. Both are used at room temperature.

The copper-nickel shell is immersed in the polysulphide bath until the copper becomes black copper sulphide and begins to peel off the nickel. It is then rinsed in water and immersed in the sodium-cyanide bath, to dissolve the copper sulphide. When only the nickel shell remains it is removed, rinsed in water, dipped in alcohol, dried and weighed. Weight of nickel shell deducted from that of the copper-nickel shell gives weight of copper plating.

(2) Only one solution is employed, containing chromic acid 500 g./L., sulphuric acid 50 g./L. It is used at room temperature. When all copper has been dissolved, the nickel shell is treated as in (1).

Thickness Calculation. Given the weight of chromium, copper and nickel, as so determined, and the area, average thickness of the respective coatings is determined according to the following formulæ:—

$$\text{Chromium, in.} \quad .. \quad \frac{\text{g. Cr} \times 0{\cdot}357}{\text{area, sq. in.}} = \frac{\text{g. Cr} \times 0{\cdot}0554}{\text{area, sq. cm.}}$$

$$\text{Copper, in.} \quad .. \quad \frac{\text{g. Cu} \times 0{\cdot}284}{\text{area, sq. in.}} = \frac{\text{g. Cu} \times 0{\cdot}0441}{\text{area, sq. cm.}}$$

$$\text{Nickel, in.} \quad .. \quad \frac{\text{g. Ni} \times 0{\cdot}289}{\text{area, sq. in.}} = \frac{\text{g. Ni} \times 0{\cdot}0448}{\text{area, sq. cm.}}$$

It is claimed that the accuracy obtained by this method is as good as, or better than, that of either the

microscopic method or of straight chemical procedures. Determinations of cyanide-copper plate thicknesses usually agree closely with those made by the microscopic method, due, it is believed, to the excellent throwing power of this bath. Nickel-plate thicknesses are usually somewhat higher, to an extent depending on the contour of the plated article.

NON-FERROUS ALLOYS

Hot Working of Metals and Alloys

'The Hot Working of Non-Ferrous Metals and Alloys. A Symposium on Metallurgical Aspects of the Subject.' *Inst. Metals Monograph and Report Series No.* 9; published by the Institute 1951; 208 pp. Price 15/-.

comprising the papers and discussion presented at the symposium held in March, 1950.

The titles of the papers contained are listed below:—

F. KASZ: 'The Hot Rolling of Aluminium and its Alloys.'

C. SMITH: 'The Extrusion of Aluminium Alloys.'

F. E. STOKELD: 'The Hot Forging and Hot Stamping of Aluminium and its Alloys.'

R. G. WILKINSON and F. A. FOX: 'The Hot Working of Magnesium and its Alloys.'

M. COOK and E. DAVIS: 'The Hot Working of Copper and Copper Alloys' (for abstract of this paper, which includes discussion of the hot working of cupro-nickel and nickel silver, see *Nickel Bulletin*, 1950, vol. 22, No. 4, p. 68).

D. W. D. SHOWELL: 'The Hot Working of Tin Bronzes.'

L. H. BACK: 'The Hot Working of Lead and Lead-Rich Alloys.'

C. W. ROBERTS and B. WALTERS: 'The Rolling of Zinc and Zinc-Rich Alloys.'

Properties of Nickel-containing Manganese Bronze

J. S. VANICK: 'Nickel-Alloyed Manganese Bronze.' *Foundry*, 1951, vol. 79, June, pp. 122-5, 226, 228.

This article is the sixth in the series describing the properties of brass and bronze alloys containing additions of nickel. For abstracts of parts 1-5 see *Nickel Bulletin*, 1950, vol. 23, Nos. 10 and 12, pp. 181 and 225; 1951, vol. 24, Nos. 3, 4 and 6, pp. 54, 77, and 133.

Manganese bronze may be broadly classified as a 60-40 copper-zinc alloy to which has been added 1 per cent. each of aluminium, iron and manganese. The A.S.T.M. definition is 'a copper-base alloy containing more than 17 per cent. zinc, with iron, aluminium, manganese, tin and nickel exceeding a total of 2 per cent.' The definition further requires 'tin to be less than 6 per cent., silicon less than 0·50 per cent. and lead close to zero or not exceeding 1·50 per cent. for the leaded grade.'

Nickel additions (up to about 3 per cent.) to manganese bronze are commonly made to assist diffusion of iron, and to retard pitting and dezincification; such additions have also a favourable effect on mechanical properties, and corrosion-resistance. Melting, casting and moulding practices for the nickel-containing manganese bronzes do not differ appreciably from those standard for regular manganese bronzes; this article briefly reviews the points of major importance in this connexion.

The strength and toughness of manganese bronzes is comparable to that of steel; specification ranges for some typical nickel-containing grades are shown in the table below.

Manganese bronze is used for a variety of large and small impellers for marine service, and in this application resistance to erosion and cavitation-erosion are of vital importance. In this connexion it has been shown that the nickel-modified bronzes offer much improved properties: comparative data are tabulated in this paper on the cavitation-erosion resistance of Turbadium bronze, Turbine Metal and nickel-free manganese bronzes (see table for compositions). A summary is also made of cavitation and erosion-fatigue tests made at the Naval Engineering Experiment Station at Annapolis, and at the Massachusetts Institute of Technology. The results of both series confirm the advantages conferred by the presence of about 3 per cent. of nickel in manganese bronze, and also indicate an even more favourable position for aluminium bronze containing about 5 per cent. of nickel.

Higher percentages of nickel, e.g. 12-15 per cent., are used with advantage in alloys of the yellow-brass type. A typical composition for sand-cast alloys is copper 45, nickel 12-15, zinc 38-42, aluminium 0·50, manganese 0·50, other elements 1, per cent. Mechanical properties of the order of 70,000 p.s.i. (31·25 tons per sq. in.) tensile strength are obtained, with elongations of about 15 per cent., and a Brinell hardness of about 150. The 10-15 per cent. nickel brasses are used in

Alloy	Cu %	Zn %	Al %	Ni %	Fe %	Mn %	Sn %	Yield Strength		Tensile Strength		Elongation, % in 2 in.	Brinell Hardness
								p.s.i.	t.s.i.	p.s.i.	t.s.i.		
Manganese bronze	57·2	41·0	0·3		0·7	0·8		33,600	15·0	71,700	32·0	25·0	129
Turbadium ..	50·0	44·0		2·0	1·0	1·75	0·5	38,100	17·0	85,100	38·0	18·0	154
Turbine metal ..	56·0	36·0	1·0	3·0	1·0	2·0		39,900	17·8	80,000	35·7	20·0	166
High-tensile brass	60·0	34·0	3·0	3·0				37,200	16·6	82,200	36·7	19·0	125
High-tensile brass	60·0	31·5	4·1	3·0	1·45			52,400	23·4	99,600	44·5	12·0	159

many applications in which good appearance is a factor of importance, combined with resistance to wear and corrosion. Typical examples include industrial valves, hardware, plumbing parts, automobile accessories, and optical instrument parts.

A composition which may be taken as typical of lower-nickel yellow brasses is copper 57, lead 1, nickel 1·75 per cent., zinc balance. Such alloys find extensive application in marine hardware.

Determination of Nickel in Manganese Bronze

G. NORWITZ: 'The Analysis of Manganese Bronze.' *Analyst*, 1951, vol. 76, May, p. 314-16.

An improved method is proposed which obviates filtrations and hydrogen-sulphide precipitations necessary in procedures generally used.

The method is based on the observation that copper and lead can be separated by electrolysis from as much as 2 per cent. of tin, by the use of a perchloric-nitric acid electrolyte. After separation of these elements, manganese, nickel, iron, aluminium and tin are determined on aliquots of the electrolyte, by means of conventional procedures. Full details are given for all determinations.

The Iron-Nickel-Aluminium System

See abstract in next column.

Spectrophotometric Estimation of Nickel in Aluminium Alloys

See abstract on p. 169.

Nickel-containing Materials in British Coinage

'The Royal Mint.' *Chemistry and Industry*, 1951, June 30, p. 499.

In connexion with the 1951 Annual Meeting of the Society of Chemical Industry, held in London in July, brief but informative notes are published on some of London's places of interest: the river, docks and warehouses; the Wallace Collection; the Victoria and Albert Museum; the Royal Mews; the Royal Mint.

The note on the Royal Mint gives a historical review of coinage development and of the present constitution and practice of the Mint, together with notes on the methods used for production of electroformed dies, the ceremony of the Trial of the Pyx, hall-marking offices operating in England, and the composition of United Kingdom coinages. The information on the coinage is reproduced below.

Gold. Sovereign. 916·6 parts per thousand of gold; remainder copper.

Silver. Prior to 1920: 925 parts per thousand of silver, remainder copper.
1920-1927: Various alloys containing 500 parts per thousand of silver, remainder copper or copper and nickel.
1927-1946: Silver 500, copper 400, nickel 50, zinc 50, parts per thousand.

Cupro-Nickel. 1946 to date: copper 75, nickel 25, per cent.

Nickel-Brass (twelve-sided 3d. piece). Copper 79, zinc 20, nickel 1, per cent.

Bronze. Copper 95·5, tin 3, zinc 1½, per cent.

Diffusion of Magnesium Through Nickel

See abstract on p. 169.

Thermal Conductivity of Nickel-containing Materials

See abstract on p. 182.

Production of Heating Elements Embodying Inconel Tubing in Copper Blocks

See abstract on p. 180.

Spinning on Automatic Lathes

See abstract on p. 183.

NICKEL-IRON ALLOYS

The Iron-Nickel-Aluminium System

A. J. BRADLEY: 'Microscopical Studies on the Iron-Nickel-Aluminium System. Part II. The Breakdown of the Body-Centred Cubic Lattice.' *Jnl. Iron and Steel Inst.*, 1951, vol. 168, July, pp. 233-44.

(In Part I of this investigation an account was given of the widening of the miscibility gap between the α face-centred cubic and β body-centred cubic structures in the iron-nickel-aluminium system; *ibid.*, 1949, vol. 163, Sept., pp. 19-30; *Nickel Bulletin*, 1949, vol. 22, No. 10, p. 158).

Body-centred cubic alloys of the iron-nickel-aluminium system may be classified as either β disordered or β′ ordered like NiAl. A very narrow two-phase gap may be traced from the melting point downwards, which does not open appreciably above 1000°C. From 950°C. to 750°C. a rapid change takes place. In each isothermal section (950°C., 850°C., 750°C.) the β and β′ region constitutes a bay which quickly increases as the temperature is lowered.

Contrary to the experience of earlier investigators, these alloys give rise to microsections which are readily recognized under oil immersion. Three main types of duplex alloy have been identified. In one, an ordered lattice is precipitating from a disordered lattice. At low temperatures islands of order are formed within the mosaic structure, and these stack together in small units to form cubes of the ordered lattice. Sometimes the corners of the cubes are rounded, or they may even form perfect spheres instead. In another type of structure disordered matter is being ejected from each mosaic cell, leaving the interior completely ordered. The ejected matter is first deposited at each corner of the mosaic, and then joins together neighbouring corners to form a continuous network. These two types of structure are formed when the disordered or ordered structures are in considerable excess.

When approximately equal amounts of the two phases are present, a lamellar tetragonal structure is formed on 001 planes, analogous to that previously found for FeCuNi, from X-ray evidence. With excess of iron, the ordered NiAl bands break up into cubes or spherules. With less iron, the disordered iron bands are no longer continuous, and in section a maze-like structure is produced

The approximately pseudo-binary sections, in which these structures are mainly to be found, contain, for the most part, slightly more Al than the vertical plane Fe-Ni-Al. With more Ni, three-phase structures are formed, showing a characteristic combination of the $\beta+\beta'$ with the $\alpha+\beta$ or $\alpha+\beta'$ patterns. The pseudo-binary planes are twisted; the exact positions of the phase boundaries therefore require extremely careful delineation.

Magnetic Properties of Columnar Alcomax

K. HOSELITZ and M. McCAIG: 'Torque Curves and Other Magnetic Properties of Alcomax.' *Proc. Physical Soc.*, 1951, vol. 64, July 1, pp. 549-59.

Using a torque magnetometer, the magnetic anisotropy of a columnar magnet of Alcomax III was investigated. The alloy was of the following composition: nickel 13·45, cobalt 25·3, copper 2·99, aluminium 7·4, niobium 0·87, silicon 0·17, per cent., remainder iron.

Three types of torque curve were obtained, depending on the heat-treatment which the magnet had undergone. After rapid cooling the type of magneto-crystalline energy is cubic, with a positive constant (iron-like); after slow cooling it is cubic, with a negative constant (nickel-like), and after cooling in a magnetic field it is uniaxial, with a positive constant (cobalt-like). Changes in crystal anisotropy are compared with parallel measurements on the hysteresis curve.

A direct experiment showed that when the field applied during cooling makes an angle with the crystal axes, the preferred direction is much nearer to a (100) axis than the field direction.

CAST IRON

Routine Foundry Production of Spheroidal-Graphite Cast Iron

M. M. HALLETT: 'Practical Experiences in Producing Nodular Cast Iron.'* *Reprint from Foundry Trade Jnl.*, 1951, vol. 90, Jan. 4, pp. 3-9; disc., pp. 9-12, 16.

Issued by Mond Nickel Co., Ltd., Pubn. 507, July, 1951; 12 pp.

For abstract of this paper see *Nickel Bulletin*, 1951, vol. 24, No. 2, pp. 34-5.

N. CROFT: 'Producing Ductile Cast Iron.'* *Reprint from Iron and Steel*, 1951, vol. 24, Feb., pp. 45-50. Mond Nickel Co., Ltd., *Publn.* 517, 1951; 10 pp.

For abstract of this paper see *Nickel Bulletin*, 1951, vol. 24, No. 3, pp. 54-5.

Impact Testing of Cast Iron

J. T. EASH and A. P. GAGNEBIN: 'An Arbitration Bar Izod Impact Test for Cast Iron.' *Amer. Soc. Testing Materials, Preprint* 15, June, 1951; 8 pp.

Conventional Izod and Charpy specimens have proved unsuitable for impact testing of engineering cast irons, due to the fact that the small specimens employed had such a low order of impact resistance that they did not serve to distinguish between many of the ordinary grey cast irons. They had the further disadvantage that the samples had to be selected from a specific location in the casting. The requirement was for a test which would evaluate the whole casting, including the undisturbed skin, instead of a section representing only a portion of the gradient structures.

In view of the existence, and use in the foundry industry, of the 1·2-in. arbitration bar, this form was selected as a basis for development of an impact test piece for cast iron. The present paper describes a test which utilizes a section of the arbitration bar and subjects it to impact in a modified Izod machine.

The design of the machine, and its mode of operation, are dealt with in considerable detail; dimensioned drawings illustrate the discussion. It is shown that the machine accommodates various types of cast iron, having impact values from 10 ft.-lb. (high-phosphorus grey irons) to over 120 ft.-lb. (austenitic irons). Typical values are tabulated for plain grey irons, irons containing various amounts of phosphorus, nickel-chromium and nickel-molybdenum engineering irons, nickel-chromium white irons, nickel-alloy chill-cast irons, and austenitic types. The results demonstrate that the test results readily reflect changes in structure, such as the presence of brittle networks, the form and quantity of graphite, and changes in the matrix structure. It is also sensitive to the metallurgical quality of the surface zones, a feature which is peculiarly useful, since most castings are used in the unmachined condition.

The arbitration bar and modified Izod test are not suitable for testing the spheroidal-graphite types of cast iron: for these the keel bar is preferred. Arbitration bars of these irons have been found to require 2-6 blows to secure fracture, and some grades of austenitic 20 per cent. nickel-alloy austenitic iron containing spheroidal graphite were still unbroken after 20 blows. For irons of such high degrees of toughness one of the Charpy or conventional Izod tests is more satisfactory.

CONSTRUCTIONAL STEELS

A.S.T.M. Specifications for Nickel-containing Steels

AMER. SOC. TESTING MATERIALS: 'Report of Committee A-1 on Steel. *A.S.T.M. Preprint* 2, June, 1951; 56 pp.

The activities of the Committee are reviewed, and modifications recommended in existing standards or tentative standards are recorded. The schedules affected include specifications relating to both high- and low-alloy nickel-containing steels.

The following new standards are proposed as tentative:—

Nickel-Chromium-Molybdenum Steel Bars for Springs

Covering steels of the following grades: 8650, 8650H, 8655, 8655H, 8660 and 8660H. The 'H' grades only are subject to hardenability requirements, as set forth in the specification. Composition limits are indicated in Table I on p. 177.

**We shall be pleased to supply free copies of these publications*

Table I.

	8650	8650H	8655	8655H	8660	8660H
Carbon %	0·48-0·53	0·46-0·54	0·50-0·60	0·50-0·60	0·55-0·65	0·55-0·65
Manganese %	0·75-1·00	0·70-1·05	0·75-1·00	0·70-1·05	0·75-1·00	0·70-1·05
Nickel %	0·40-0·70	0·35-0·75	0·40-0·70	0·35-0·75	0·40-0·70	0·35-0·75
Chromium %	0·40-0·60	0·35-0·65	0·40-0·60	0·35-0·65	0·40-0·70	0·35-0·65
Molybdenum %	0·15-0·25	0·15-0·25	0·15-0·25	0·15-0·25	0·15-0·25	0·15-0·25

In all cases sulphur and phosphorus are specified as 0·040 max. each, and silicon is 0·20-0·35 per cent. for all grades.

Hardenability tests on the 'H' grades are to be made by the end-quench method laid down in A.S.T.M. Designation A255.

Alloy Steel Seamless Drum Forgings

This specification covers forged alloy-steel hollow drums and headers for use in pressure vessels, and also alloy-steel forgings for heads, cover, plugs and other component parts for pressure vessels. Twelve classes of steel are covered, including eight ferritic steels and six austenitic steels, of the following types:—

Ferritic: carbon-molybdenum, chromium-molybdenum of three grades, 13% chromium, molybdenum-vanadium, nickel - molybdenum - vanadium, nickel - chromium-molybdenum-vanadium.

Austenitic: straight 18-8 chromium-nickel, 18-8 modified with additions of molybdenum, niobium or titanium; nickel-chromium 20-8 per cent., and chromium-nickel 25-20 per cent.

Seamless and Welded Steel Tubes for Low-Temperature Service

The composition of the three ferritic grades covered is shown below:—

Table II.

Grade	C %	Mn %	P % max.	S % max.	Si %	Ni %
C	0·25	0·64-1·06	0·050	0·060	—	—
3	0·19	0·31-0·64	0·050	0·050	0·18-0·37	3·18-3·82
5	0·19	0·20-0·64	0·050	0·050	0·18-0·37	4·68-5·32

Room-temperature tensile tests are specified, also flattening, flaring, and hardness tests, and impact-test requirements are laid down, for grade C at −50°F. (−46°C.), and for grades 3 and 5 at −150°F. (−101°C.). A hydrostatic test is also required prior to upsetting, swaging, expanding, bending or other forming operations.

The report also includes proposed tentative specifications for—

Carbon Steel Sheets of Flange and Firebox Qualities, and

Seamless Ferritic Alloy Steel Pipe for High Temperature Service,

covering piping of carbon-molybdenum, chromium-molybdenum, chromium-molybdenum-silicon, chromium-molybdenum+titanium or niobium, molybdenum-silicon, and 7 and 9 per cent. chromium steels containing small percentages of molybdenum.

Composition of S.A.E. 4340 Nickel-Chromium-Molybdenum Steel

H. W. McQUAID: 'The Birth of S.A.E. 4340.' *Metal Progress*, 1951, vol. 59, May, pp. 669-70.

A note giving the factors which led to selection of composition limits for this popular steel, the specification for which stands as carbon 0·38-0·43, manganese 0·60-0·80, nickel 1·65-2·00, chromium 0·70-0·90, molybdenum 0·20-0·30, per cent.

The steel was developed from the earlier 3240 steel by *lowering of chromium* (to improve transverse impact value), *raising of manganese* (to improve response to quenching and to give better melting properties and cleaner steel), and *addition of molybdenum* (to improve response to quenching and to obtain more uniform martensite with less free ferrite). Fine grain size was also specified from the earliest days of this steel, which was initially designed to meet the requirements of rear-axle components in heavy-duty trucks.

Influence of Hardness on Temper Brittleness in Nickel-Chromium Steel

D. C. BUFFUM and L. D. JAFFE: 'Effect of Hardness on Temper Brittleness.' *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1951, vol. 191, p. 540; *Jnl. of Metals*, July, 1951.

Temperature of transition from tough to brittle fracture is used as a means of assessing embrittlement which has occurred on cooling of steels after tempering, and since hardness is known to affect transition temperature, a study of the combined influence of hardness and temper brittleness was considered desirable.

A commercial grade of S.A.E. 3140 steel (previously studied in investigations of temper brittleness (*Trans.*

Amer. Soc. Metals, 1950, vol. 42, pp. 604-14) was used. Blanks of the steel were austenitized for one hour at 900°C. and water quenched. They were then divided into six groups and heat-treated as follows:—

Group 1. Tempered at 675°C. for 4 hours; water quenched.

Groups 2, 3, 4, 5. Tempered at 675°, 650°, 625° and 600°C., respectively, for 1 hour; water quenched.

Material from each of these groups was divided into two parts; one was tested without further heat-treatment, the other was embrittled by heating for 48 hours at 500°C., followed by water quenching.

Standard V-notch Charpy bars were prepared from the blanks so treated, and were tested, on a 217 ft.-lb. machine, over a range of temperatures (exact limits not given). Energies required to fracture, and percentage of fibrous fracture in each bar were recorded, and transition temperatures were obtained from a plot of the percentage of fibrous fracture as a function of test temperature; the value taken was the lowest point at which the fracture was 100 per cent. fibrous. Transition temperatures for both tough and embrittled specimens are shown as a function of hardness.

From the data obtained it is concluded that at any given hardness within the range Rockwell C 24½ to 32½, difference between transition temperatures for the embrittled and the unembrittled conditions of the steel is constant. The results also indicate that, within the hardness range studied, the transition temperatures for embrittled and unembrittled specimens rise in parallel manner with increase in hardness.

Hot Extrusion of Nickel-Chromium-Molybdenum Steel Propeller Blades

'Alloy Steel Prop Blades made by Hot Extruding.' *Materials and Methods*, 1951, vol. 33, May, pp. 66-7.

The past two years have witnessed increasing interest in the hot extrusion of steel, and certain steelmakers in U.S.A. have announced early commercial availability of extruded steel tubing of various cross-sectional shapes.

The first commercial application of hot steel extrusion is believed to be in the production of hollow steel propeller blades, a development jointly sponsored by Curtiss-Wright Corporation and the U.S. Air Force.

This article gives a pictorial survey of the operations involved in production of the propellers, starting with the removal of the nickel-chromium-molybdenum steel ingot from the salt-bath furnace, through to inspection of the completed blades. One of the many advantages associated with this method of manufacture is the saving in material which is effected by extrusion. By the methods formerly used, 750 lbs. of steel were required to make a 10-ft., 200-lb. blade. By extruding, the initial requirement is for a 400-lb. ingot, and, in addition, considerable savings are realized in machining time necessary for production of the final shape.

Stability Tests on Alloy Steels under Prolonged Exposure to High Temperatures

See abstract on p. 180.

Surface Hardening of Steel

G. T. COLEGATE: 'The Surface Hardening of Steel. Part IV.' *Metal Treatment*, 1951, vol. 18, Apr., pp. 163-70.

One of the most important factors involved in pack carburizing is the choice of design and material of the boxes: many considerations are involved, e.g., length of life required, size of work being treated, etc. Generally speaking, although plain carbon steels are sometimes used for this purpose, the modern carburizing container is made of a heat-resisting alloy steel, or of a non-ferrous material containing high percentages of nickel and chromium. In some cases an aluminium coating, applied by Calorizing, is used to enhance resistance to deterioration in carburizing service.

Cast materials are very widely used for carburizing boxes, but it is essential, if satisfactory service and long life are to be obtained, that the casting technique should be of a high order, and that suitable design should be used.

Energizers used in carburizing compounds have a deleterious effect on containers, irrespective of the material from which they are made, and container deterioration may also be influenced by the type of fuel used in the furnace. In general, electrically heated furnaces permit a longer container life than do gas-fired furnaces, in which sulphur attack is a harmful factor. Careless handling, overloading, and the placing of containers unevenly in the furnace, are other avoidable variables which may have injurious effects and substantially shorten life. Provided that a defect is discovered at a sufficiently early stage, repair of containers may often be effected by welding, but it is emphasized that such repair is a matter for a skilled operative.

Container design is a matter of primary importance, both with regard to efficiency in service, and length of life. Recommendations are made by the author with regard to (1) methods which may be adopted to ensure even heating, and (2) shapes which will be most suitable for various kinds of service. Other things being equal, it is considered that a cylindrical container will have a longer life than a square one, on account of its more regular shape and the smaller risk of occurrence of thermal stresses which may induce cracking.

It is urged that careful attention should also be given to the mode of packing of carburizing boxes. Practical recommendations are made as to packing of items of unusual shape, handling and ramming of the compound, the actual packing operation, and avoidance of placing which would lead to sagging and distortion.

Brief reference is made to the practice of paste carburizing, a method which, although not widely used, is claimed to have the advantage of being quicker than pack carburizing, giving a more uniform case depth, avoiding production of cementite in the outer layers of the case, minimizing distortion, and lessening scaling.

As stopping-off material copper-plating is usually employed, and in cases of holes or slots which cannot be treated by plating, a paste of waterglass and fireclay may be used.

The final section of this instalment deals briefly with the types of furnace which may be used for pack carburizing, and methods for ensuring the most economical utilization of both furnace and container. Typical modern electric pack-carburizing furnaces are illustrated.

'Part V. Gas Carburizing.' *ibid.*, June, pp. 249-56.

This article makes a useful review of the three groups of gases which may be present in the furnace in gas carburizing: carburizing, decarburizing, or neutral. By an alternative classification, the gases may be considered as oxides of carbon, hydrocarbons, and non-carbonaceous gases such as hydrogen, water vapour and nitrogen. Properties of the respective types are described and the relationship between them is considered.

A brief note is added on catalytic effects which may be exerted by water vapour or by catalytic metals. Finally, brief consideration is given to the case depth and carbon gradient, as affected by the type of gas used and the time and temperature of treatment.

By comparison with pack carburizing and with cyaniding, gas carburizing is a comparatively new commercial process, and its development was at first relatively slow, due to lack of understanding of the reactions taking place between the various gases used and the steel. Considerable investigation has, however, been carried out during recent years, the process is now firmly established, and there is, on both the British and American markets, a wide range of equipment for production of suitable atmospheres, and of furnaces in which the treatment can be carried out.

The outstanding characteristics of gas carburizing are (1) the wide range of case depths which can be obtained by varying time and temperature of treatment in any given atmosphere, and (2) the greater variety of case properties producible by variation in the gases used. The process has the following additional advantages: it is better adapted to direct quenching from the carburizing temperature than is pack carburizing, it obviates the need for packing boxes with carburizing compound, and it is quicker than pack carburizing, due to elimination of the time required for packing and heating containers. On the adverse side, gas carburizing calls for a greater degree of skill on the part of the operator, and a closer understanding of the technical aspects of the subject. The higher initial cost involved in gaseous treatment is offset by lowering of operating costs.

Thermal Conductivity of Nickel-containing Materials

See abstract on p. 182.

Properties of Nickel-Alloy Steels for Marine-Propulsion Gears

M. R. GROSS: 'Laboratory Evaluation of Materials for Marine-Propulsion Gears.' *Amer. Soc. Testing Materials, Preprint* 38, June, 1951; 16 pp.

Immediately after World War II the Bureau of Ships of the U.S. Department of the Navy inaugurated a programme to reduce the weight and space requirements of many shipboard components. Considerable attention has been focused on reduction in weight of propulsion gearing. New types of high-speed lightweight propulsion gears have been designed and constructed, and extensive facilities have been set up for testing of experimental gears under full-scale conditions.

At an early stage in the work it was realized that large-scale destructive tests would be very expensive, and that such tests could be conducted on only a limited number of gears. It was therefore decided to conduct relatively inexpensive laboratory tests in order to evaluate various materials and treatments, and, if possible, to correlate the data so obtained with results of full-scale destructive tests. This paper describes the nature of the laboratory tests devised for this purpose, and presents results evaluating some of the materials used, or potentially applicable, for gearing.

The primary object of the experiments made was to determine resistance to pitting, and the root fatigue strength. A contact-roller-test machine is described, on which pitting limits were determined for the following materials:

Steels: S.A.E. 1035 carbon; nickel-molybdenum (2½/¼%); nickel-chromium-molybdenum-vanadium (2½/1/½/¼%); chromium-molybdenum (5/½%); N.E. 8615 (low-alloy nickel-chromium-molybdenum), and S.A.E. 4615 (nickel-molybdenum).

Non-Ferrous Materials: Wrought and sand-cast aluminium alloys; copper-beryllium alloy, precipitation hardened; sand-cast and aged Dowmetal, and a manganese-copper alloy (78-22%).

Plastics: Five non-metallic materials were also tested, comprising one unlaminated polyamide resin, and four laminated phenolic resins having a woven cotton-fabric filler.

The author also describes a new test designated 'the simulated gear tooth fatigue test', developed to evaluate the root fatigue strength of materials under reversed bending stresses. The materials used in this series of tests were the first three steels mentioned above, and the experiments included determination of the influence of surface-hardening treatments of various types, and shot-peening, and the effect of root radii and surface finish.

It was found that the contact-roller test produces pits which, apart from size, are identical with those found in actual gear failures. It was thus possible, for the metallic materials, to establish a stress-cycle relationship, and to determine a 'pitting limit' for the various materials and treatments. In testing non-metallic materials, it was found necessary to alter the criteria for failure, due to the heterogeneity of the plastic-base substances. Instead of a pitting limit, a 'breaking-limit' was determined for these materials.

It is emphasized that the information given in the paper permits only qualitative comparison of pitting resistance and root fatigue strength. The numerical figures have little significance in actual gear calculations, since their values are dependent upon the geometry of the specimen and the criteria used in determining failure. The value of the data now presented lies in providing an estimate of the expected behaviour of various materials and the effects of

various treatments, based on the performance of gear materials which have been in use for many years. With few exceptions, the conclusions reached have been found to correlate satisfactorily with results of large-scale destructive tests.

Spectrophotometric Estimation of Nickel in Steel

See abstract on p. 169.

HEAT- AND CORROSION-RESISTING MATERIALS

D.T.D. Specifications for Nimonic Alloys

G. M. HUTT: 'Aircraft Materials.' *Metal Industry*, 1951, vol. 78, June 29, pp. 527, 529.

A new Numerical and Classified List of D.T.D. Aircraft Material Specifications, issued by the Ministry of Supply, Directorate of Materials Research and Development (Air), contains reference to 413 current specifications, of which 187 cover metallic materials.

The list includes five specifications for the Nimonic series of alloys. The numbers of these specifications are shown below, with notes on the main characteristics of the materials covered. For further details, reference is directed to abstracts which have appeared in *The Nickel Bulletin* at the times of publication of the individual specifications (1950, vol. 23, Nos. 8-9, and 12, pp. 157 and 233.)

D.T.D. 703.	Nimonic 75	80-20 alloy in which carbon and titanium are used as hardening additions.
D.T.D. 714.	Nimonic 75F	An alloy of closely similar composition, but containing a higher percentage of iron.
D.T.D. 725.	Nimonic 80	In both alloys titanium and aluminium are the hardening agents. The specifications are noteworthy as being the first D.T.D. schedules to embody requirements for creep tests. For Nimonic 80 creep-test requirements are specified at three temperatures, 650°, 700° and 750°C., and for Nimonic 80A a more severe test is specified at 750°C.
D.T.D. 736.	Nimonic 80A	
D.T.D. 747.	Nimonic 90	A modified alloy in which 20 per cent. of nickel is replaced by cobalt. Creep test (2 tons per sq. in. higher than that required for Nimonic 80A) is specified, at 750°C.

British Gas Turbines: Historical Review

See abstract on p. 168.

A.S.T.M. Specifications for Nickel-containing Steels

See abstract on p. 176.

Nickel Alloys in Heating Elements

F. J. LAMBERT: 'Casting-in of Inconel Tubes in Copper Blocks.'
Metal Progress, 1951, vol. 59, June, pp. 809-91.

The article describes problems encountered in making heater elements which formed an important part of equipment used at Oak Ridge in connexion with separation of uranium isotopes. A form of heater found particularly satisfactory consisted of a copper alloy casting in which was embedded a heating element similar to the type used in electric ranges, comprising a nickel-chromium alloy filament centred in a welded Inconel tube and insulated from it by tamped magnesia.

Stability Tests on Alloy Steels under Prolonged Exposure to High Temperatures

G. V. SMITH, W. B. SEENS, H. S. LINK and P. R. MALENOCK: 'Microstructural Instability of Steels for Elevated Temperature Service.' *Amer. Soc. Testing Materials, Preprint* 28, June, 1951; 18 pp.

The paper describes the effect of exposure, for 10,000 hours (about 14 months), at 900°, 1050° and 1200°F. (482°, 565° and 650°C.) on microstructure, room-temperature hardness, and notch-impact strength at various temperatures, of the ferritic and austenitic steels shown in the Table on p. 181. All the steels tested were of types potentially suitable for, or in regular use at, elevated temperatures.

The conditions in which the steels were exposed, and the test procedure, are detailed in the paper, and the results are presented in a series of curves, charts, and micrographs giving correlation of properties and structure of each of the steels, as affected by the exposures described.

From these data the following conclusions are drawn:—

'Notch-impact strength was impaired in about two-thirds of the exposures; in another 25 per cent. it was essentially unaffected; in the remaining 10 per cent. it was improved. In terms of temperature of exposure, impairment occurred in 13 steels at 1050°F. and also at 1200°F., and in 8 steels at 900°F. Improvement was observed in two steels at each of the exposure temperatures, whereas no change occurred in eight steels at 900°F., but in only three was this the case at 1050°F. and at 1200°F. The two steels which, in terms of notch-impact strength, were relatively unaffected by exposures at all temperatures of test were the 9 per cent. chromium+1 per cent. molybdenum type and the 12 per cent. chromium steel.

'Microstructural changes were, as would be anticipated, intensified with rise in temperature of exposure. In the ferritic steels carbide spheroidized, and in some instances a finely dispersed precipitate of the type previously reported in molybdenum steels was observed. In the steels of lowest alloy content complete decarburization occurred during exposure at 1200°F. No graphitization was observed in any of the steels.

'In the austenitic grades, both carbides and sigma precipitated in the 18-8-Mo-Nb, 18-8-Ti and 18-8-Nb types. Sigma was also observed in the 17 per cent.

Chemical Compositions of Steels Tested

Type of Steel	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	N %	Al %	Other Elements %
½ Mo; Si deoxidized	0·16	0·85	0·020	0·019	0·24	—	—	0·51	0·005	0·010	—
½Mo; Si+Al .. deoxidized	0·13	0·52	0·012	0·021	0·16	—	—	0·52	0·005	0·044	—
½ Cr, ½ Mo ..	0·15	0·50	0·010	0·022	0·21	0·07	0·48	0·53	0·005	0·008	—
1 Cr, ½ Mo ..	0·12	0·45	0·013	0·015	0·74	—	1·13	0·50	0·011	0·010	—
3 Cr, 1 Mo ..	0·11	0·45	0·011	0·021	0·39	0·21	3·21	0·97	0·016	0·001	—
5 Cr, ½ Mo ..	0·13	0·42	0·030	0·017	0·22	—	4·69	0·47	0·021	0·004	—
5 Cr, ½ Mo (Ti)	0·05	0·40	0·006	0·011	0·31	—	5·19	0·51	0·007	0·075	0·055 Ti
9 Cr, 1 Mo ..	0·09	0·44	0·022	0·021	0·65	0·28	8·94	0·89	0·025	0·017	—
12 Cr (Type 410)	0·06	0·45	0·008	0·017	0·32	0·07	12·24	0·02	0·029	0·009	—
12 Cr, ½ Mo ..	0·07	0·40	0·027	0·007	0·29	0·27	12·26	0·49	0·029	0·004	—
17 Cr, (Type 430)	0·10	0·41	0·021	0·014	0·46	0·36	17·00	—	0·076	0·006	0·13 Cu
18 Cr, 8 Ni (Type 304)	0·05	0·53	0·008	0·005	0·61	10·72	18·53	—	0·028	0·005	—
18 Cr, 8 Ni (0·03 C)	0·028	0·61	0·011	0·009	0·55	10·35	19·30	—	0·032	0·004	—
18 Cr, 8 Ni (Mo) (Type 316)	0·07	1·53	0·036	0·007	0·51	12·80	16·76	2·15	0·053	0·007	0·05 Cu
18 Cr, 8 Ni (Mo) (0·03 C)	0·022	1·47	0·013	0·023	0·34	10·68	17·56	2·00	0·032	0·005	—
18 Cr, 8 Ni (Mo, Nb)	0·05	0·79	0·018	0·006	0·37	14·16	18·68	2·15	0·063	0·016	0·51 Nb
18 Cr, 8 Ni (Ti) (Type 321)	0·07	0·52	0·021	0·003	0·39	10·40	17·97	—	0·011	0·069	0·58 Ti
18 Cr, 8 Ni (Nb) (Type 347)	0·06	1·43	0·018	0·006	0·44	11·16	17·80	—	0·027	0·010	0·77 Nb

chromium steel and in a segregated region of the E.L.C. 18-8 chromium-nickel steel. Attention is also directed to the discovery and identification of a carbide network in the E.L.C. grades.

'Changes in hardness in most cases reflected changes in microstructure. In general, the low- and high-alloy ferritic steels showed the greatest change in hardness, whereas in the intermediate ferritic steels and in the austenitic grades (with the exception of the 18-8-Mo-Nb and 18-8-Mo) the hardness changes were relatively minor.'

It is emphasized that the stability of any grade of steel under given conditions depends not only on its chemical composition but also on prior treatment.

Cerium Additions to Promote Ductility in High-Alloy Steels

'New Cerium-Bearing Alloy Steels Offer Greater Hot Ductility.' *Steel*, 1951, vol. 128, June 4, p. 98.

Carpenter Steel Company announces results of prolonged study of the influence of cerium and lanthanum in corrosion- and heat-resisting steels. A series of patents has been taken out on the use of these elements for increasing the hot ductility of nickel-chromium steels of the A.I.S.I. 309, 310, 316, 317 and 330 (18-8 and modified types), Carpenter Stainless 20 (containing nickel, chromium, copper and molybdenum), and various austenitic valve steels. The method is broadly applicable to high-temperature ferrous alloys containing nickel and one or more of the elements chromium, molybdenum, cobalt, copper, tungsten, silicon, manganese, niobium and vanadium. The nickel content of the materials determines the minimum and maximum allowable ranges of cerium and lanthanum giving optimum hot-workability; as the nickel content rises the cerium-lanthanum range narrows. This note is illustrated by examples demonstrating the forgeability of Carpenter Stainless 20 containing various amounts of the addition elements.

Embrittlement of Nickel-Chromium Heat-Resisting Steels by Zinc

'Zinc Embrittlement. Effect of Die Material on Drop-Hammer Pressings.'
Aircraft Production, 1951, vol. 13, July, p. 201.

The article reports investigation of a case of embrittlement observed in the plant of Airspeed, Ltd. in a heat-resisting steel to specification D.T.D. 493 (carbon 0·20 max., silicon 0·20 min., manganese 1·0

max., sulphur 0·05 max., phosphorus 0·05 max., nickel 14-22, chromium 20-26, titanium 0·50 min., per cent.)

Cracks developed, after heat-treatment, in exhaust manifold pressings, and it was found that the cracks were in a similar position on each pressing of a given type. Typical examples are illustrated.

Tests by the suppliers of the steel, and by the manufacturers of the manifolds, established that the material was up to specification requirements and that the cracking was not associated in any way with the condition of the steel as received. Close investigation of heat-treatment procedure and other variables demonstrated that there had been considerable pick-up of zinc from the drop-hammer tool used in the forming operation. Both punch and die were of zinc-base alloy and had been found to be wearing badly after forming a number of pressings.

Tests were therefore made by surface-impregnating the steel with zinc (by pressing filings into the surface under a hydraulic press), and by placing zinc filings on the surface, without applied pressure. The two sets of specimens so treated were then heat-treated in a gas-fired muffle at 1050°C., soaked for 10 minutes, and water-quenched. The ductility of the samples was studied by means of bend tests. The surface of the specimen impregnated with zinc under pressure developed cracks similar to those observed in the pressings, whereas the ductility of the specimens carrying a surface layer of filings, unpressed, was satisfactory.

Following these tests a number of body pressings were pickled immediately after the drop-hammer forming operation, to remove any adhering zinc, and were subjected to standard heat-treatment, trimmed to template, and welded. The specimens so treated showed no evidence of cracks.

In view of these results a pilot pickling plant was set up, for treatment of pressings immediately after forming. The pickling bath is a nitric-hydrofluoric acid solution, and pickling is followed by a cold-water wash. Introduction of this step in the cycle of operations has entirely eliminated cracking, clearly demonstrating that it was caused by zinc impregnation. It is believed that at the temperature of heat-treatment the adhering zinc becomes gaseous, and is diffused into the grain boundaries of the steel.

Resistance of Nickel-containing Materials to Exhaust Gases containing Lead Bromide

'Ceramic Coatings Prevent Exhaust Gas Corrosion.' *Steel*, 1951, vol. 128, June 18, pp. 98, 101, 104.

The article is based on work recently completed at the National Bureau of Standards. Five materials were tested: Inconel, Types 347 and 19-9 DL stainless steels, Vitallium, and S-816. Each material was exposed in five different conditions: (1) uncoated, (2) pre-oxidized, (3)-(5) ceramic coated. The coatings used were all of commercially available types. The specimens were exposed to lead-bromide vapour for periods up to 6 hours, in air atmosphere, at temperatures of 1350°, 1500° and 1650°F. (732°, 815° and 899°C.), being examined at hourly intervals.

The results reported indicate that resistance to attack varied widely. In the uncoated condition all five materials suffered corrosion at all test temperatures, but the total loss of thickness in the 6-hour period varied over the range 1·2 to 10·1 mils. S-816, Vitallium and Inconel were notably more resistant than 19-9-DL and the Type 347 stainless steel, on both of which a selective attack was observed, with formation of a spongy layer near the surface. With the other materials but little selective penetration was found.

Pre-oxidation of the surfaces (heating for 4 hours in air at the test temperature) tended to retard corrosion for the first hour or two only.

No consistent relation was found between temperature and rate of corrosion: some of the alloys showed less severe attack at the higher than at the lower temperatures. In this connexion it is pointed out, however, that lead-bromide concentration probably dropped off more rapidly with time at the higher temperatures.

Thermal Conductivity of Nickel-containing Materials

'Thermal Conductivity of Various Materials vs. Temperature.' *Materials and Methods*, 1951, vol. 33, June, p. 107.

Chart showing thermal-conductivity values, as function of temperature over various ranges, for the following materials:—aluminized steel, pure iron, cast iron, wrought nickel, low-carbon steel, S.A.E. 4140 chromium-molybdenum steel, Inconel-clad nickel, stainless-clad steels (cladding of Types 430, 302, 321 and 347), Inconel 'X', and Vitallium (Haynes Stellite 21).

'Partial Stabilization' of Stainless Steels

S. F. URBAN: 'Partial Stabilization of Stainless Steels.' *Metal Progress*, 1951, vol. 59, June, p. 815.

The writer comments on a suggestion made by D. C. BUCK (in discussion of the use of titanium vs. niobium in stainless steels; *ibid.*, 1950, vol. 58, Nov., pp. 704-5), with regard to determination of the influence of varying amounts of titanium as stabilizer. In this connexion Urban records experiments made by Titanium Alloy Manufacturing Company, indicating that partially stabilized steels are of doubtful value.

This conclusion is based on tests in which 18-8 was produced to a carbon specification of 0·15 per cent. and an attempt was made to stabilize part of the carbon with titanium, in percentage calculated to reduce the final effective carbon content to a figure falling within the 0·07 per cent. max. range. A laboratory heat of the following composition was prepared:—carbon 0·07, manganese 1·31, silicon 0·25, chromium 17·30, nickel 10·23, per cent. One portion of this was poured as such, and the carbon content of the remainder was raised to 0·16 per cent. by addition of a carbon spiegel. Part of this was poured, and to the remainder an addition of titanium was made sufficient to stabilize carbon in excess of 0·07 per cent.

The ingots were forged, annealed at 1950°F. (1066°C.), heated for 2 hours at 1250°F. (677°C.), and air cooled. Analyses of the respective heats, and their behaviour in the bend test, after 100 hours in a modified Strauss solution, were as shown on p. 183.

C %	Ti %	Bend-Test Results
0·07	0·0	Orange peel and fine cracks
0·16	0·0	Cracked completely
0·13	0·31	Cracked completely

The writer offers the interpretation that, in the 18-8-base composition, with the carbon ranges mentioned, complex carbides are formed which are different from titanium carbide and that the whole of the titanium added therefore does not act in a stabilizing manner. It is anticipated that similar conditions will prevail if partial stabilization with niobium is attempted.

Properties of Austenitic Nickel-Chromium Steels

'Austenitic Stainless Steels.'
Materials Data Sheet No. 208.
Materials and Methods, 1951, vol. 33, May, pp. 99, 101.

This chart, prepared with the assistance of Carnegie Illinois Steel Corporation and Armco Steel Company, comprises reference data on the average physical and mechanical properties of the steels shown below, and notes on their heat-treatment, fabricating properties and general corrosion-resisting qualities.

A.I.S.I.	C %	Mn %	Si %	P %	S %	Cr %	Ni %	Other Elements %
301	0·08-0·20	2 max.	1 max.	0·04 max.	0·03 max.	16-18	6-8	
302	0·08-0·20	2 max.	1 max.	0·04 max.	0·03 max.	17-19	8-10	
303	0·15 max.	2 max.	1 max.	*	*	17-19	8-10	Se*; Mo or Zr 0·60 max.
304	0·08 max.	2 max.	1 max.	0·04 max.	0·03 max.	18-20	8-11	
304 ELC	0·03 max.	2 max.	1 max.	0·04 max.	0·03 max.	18-20	8-11	
309	0·20 max.	2 max.	1 max.	0·04 max.	0·03 max.	22-24	12-15	
316	0·10 max.	2 max.	1 max.	0·04 max.	0·03 max.	16-18	10-14	Mo 2-3
316 ELC	0·03 max.	2 max.	1 max.	0·04 max.	0·03 max.	16-18	10-14	Mo 2-3
321	0·08 max.	2 max.	1 max.	0·04 max.	0·03 max.	17-19	8-11	Ti 5 x C

* For type 303 P, S or Se specified as 0·07% min.

Spinning of Austenitic Nickel-Chromium Steel

'Automatic Spinning of Stainless Steel in Production.'
Materials and Methods, 1951, vol. 33, May, pp. 86-7.

International Harvester Company has for some years past intensively studied development of spinning methods suitable for large-scale production of parts in stainless steels and other materials. This article describes (with good illustrations) the procedure evolved for making cream-separator bowls, which are produced in four sizes, using automatic spinning machines.

Prior to introduction of the spinning method, these bowls were drawn by ordinary press operations. Two annealing treatments were required to compensate for work hardening, and cleaning was necessary after each annealing. In addition, the drawing operation itself presented some difficulty. The use of the spinning method has eliminated the need for annealing and cleaning, and the work moves from the spinning machine immediately into the presses built into the processing unit.

Spinning on Automatic Lathes

D. REEBEL: 'Metal Spinning now a Mass-Production Tool.' *Steel*, 1951, vol. 128, June 4, pp. 88-91, 114.

The article is a discussion of the wide potential value of the spinning process as a production method. It is particularly well illustrated, by photographs and diagrams showing the various stages of spinning high-voltage caps in straight-chromium stainless steel of the 430 and 446 types, using automatic spinning lathes which have made possible the processing of materials previously considered incapable of undergoing such forming operations.

A table accompanying the paper gives a comparative rating of the adaptability of various metallic materials (ferrous and non-ferrous) to shallow or deep spinning. Ratings for nickel, Monel, Inconel, cupro-nickel and nickel silver alloys are included.

Production of Stainless-Steel Wire

'American Steel and Wire Stainless Steel Plant at Waukegan.' *Wire and Wire Products*, 1951, vol. 26, May, pp. 394-7, 439.

The new wire mill described is a subsidiary of United States Steel Corporation, and has been specifically laid out to provide for a rated capacity of 500 tons of stainless-steel wire per month. Equipment and procedure are described throughout the plant, from rod storage to final inspection and dispatch. The article includes illustrated notes on the annealing furnaces and their operation, the cleaning department (in

which an electrically heated salt-bath furnace is employed, and various forms of acid pickling are used), wire-drawing equipment and methods, processes used for annealing of fine wire, straightening and cutting equipment, cold rolling of flat wire, and final testing and inspection.

Production of Fine Stainless-Steel Wire by Electropolishing

W. H. COLNER, M. FEINLEIB and H. T. FRANCIS: 'Preparation of Very Fine Wire by Electropolishing.' *Metal Progress*, 1951, vol. 59, June, pp. 795-7.

Mechanical production of very fine wire (down to, say, 0·0003-0·0004 in. diameter) is an expensive and time-consuming operation, from the point of view of both equipment and processing. Research has therefore been carried out, by Armour Research Foundation, on the application of electropolishing methods. In the process described the wire is fed through the bath at a steady rate and under constant electrical conditions, with the result that all parts receive the same treatment and the wire emerges with a uniform cross section. The set-up devised for the process is described and illustrated, and operations are detailed as typified by production of fine wire of 18-8 stainless steel.

The two starting sizes used in the treatments described were 0·001 in. annealed, and 0·0004-in. hard-drawn, wires. The bath found to give the best results for this material was of the following composition:

Phosphoric acid (85%)	125 c.c.
Water	30 c.c.
Citric acid	50 g.
Ethyl alcohol (95%)	10 c.c.

The composition can be varied over a relatively wide range without appreciably affecting the polishing action, and the authors consider that any solution commonly used for electropolishing stainless steel would be suitable. Some notes are given on operating conditions, on precautions to be observed at various stages of the process, and on the influence of speed of movement of the wire, temperature, and other variables. It is shown that stainless-steel wire, and wire of other metals and alloys, may be reduced in diameter far below limits possible of production by conventional wire-drawing practices, by controlled electropolishing. The finest size of wire which the authors have succeeded in producing is 0·00013 in. diameter, but it is believed that a still finer gauge might be made by some refinement of the electropolishing apparatus.

Effect of Welding on the Corrosion-Resistance of Stainless Steels

E. W. HOPPER: 'Welding and its Effect on the Corrosion Resistance of Stainless Steel.' *Welding Jnl.*, 1951, vol. 30, June, pp. 503-7.

This paper, written by the chief chemical engineer of the Crucible Steel Company of America, is not intended to present theoretical aspects of intergranular corrosion, but is concerned solely with a practical consideration of failures typical of those occurring in industries in which corrosive solutions are handled. Causes of such failures are discussed, and constructive suggestions are made for prevention or correction.

Following an introductory note on the limitations of titanium-stabilization, and the current conditions which render it difficult to obtain niobium, the writer urges the use of the extra-low-carbon grades. Tests are quoted to indicate the degree of freedom from intergranular corrosion obtainable by this means.

Typical cases of failure due to carbide precipitation and intergranular attack are then discussed and illustrated, and the extent to which such a condition can be corrected by annealing treatment is indicated. In connexion with the use of niobium-stabilized welding rods, it is emphasized that there is no advantage to be gained by the use of either a niobium-stabilized or an extra-low-carbon rod for welding of unstabilized stainless steel of normal carbon content. The welding rod cannot correct the condition arising in the heat-affected zone of the parent material. Conditions in which protected-atmosphere welding will be beneficial are considered, vis-à-vis conditions in which welding with coated rods is to be preferred.

Particular attention is directed to the considerable advantages to be obtained by rapid cooling of welds, preferably by water, applied as a small stream or spray, or by swabbing the surface with a wet sponge. Where the weld is followed by a fine stream of water, at a short distance, say 6-8 in., continuous welding can be carried on. In other cases, not longer than one minute of uninterrupted welding, from the time the arc is struck, should be allowed to elapse before swabbing is applied. To demonstrate the value of this procedure, a comparison is made of a typical case in which tubing of a 0·1 per cent. carbon nickel-chromium stainless steel was welded (1) with water cooling, and (2) by normal practice.

Identification Tests for Stainless Nickel-Chromium Steels

A. W. SMOLLA: 'Identification of 3 Stainless Alloys Simplified.' *Iron Age*, 1951, vol. 167, June 21, pp. 97-8.

This short note describes rapid test methods developed at Crucible Steel Company's works, for identification of Types 316, 321 and 347 stainless steels. The determinations are made on trim scrap, thus avoiding expenditure of time on milling or drilling of samples.

Type 316 (containing molybdenum): Reagents required; 60% perchloric acid; sodium thiocyanate, 50 g. dissolved in 1,000 ml. of water; stannous chloride, 250 g. dissolved in 200 ml. of chemically pure hydrochloric acid, diluted to 1,000 ml. with water.

The material to be tested, in the form of 1 × 1½ × 4-in. pieces of scrap, is placed in a 150 ml. beaker, an addition of 10 ml. of perchloric acid (60%) is made and the beaker is placed on a stove until reaction begins (in about 20 seconds). The sample is removed from the beaker and the beaker is taken off the stove. The test solution is diluted to about 30 ml. with water, 5 ml. of sodium thiocyanate is added, followed by 10 ml. of stannous chloride solution. A decided reddish colour indicates presence of molybdenum.

Type 321 (containing titanium): In general, the same procedure is adopted as with 316, but the dissolving

time required is slightly longer, about 30 seconds. After diluting to 30 ml. with water, one or two drops of hydrogen peroxide are added. If the sample contains titanium a distinct brownish colour will result.

Type 347 (containing niobium or niobium+tantalum): In this case considerably more metal must be dissolved: about 60 seconds in perchloric acid is sufficient. After removal of the sample a few drops of hydrofluoric acid are added and the solution is fumed. The beakers are then removed from the stove and the sample is diluted to 30 ml. with water. Presence of niobium or niobium+tantalum will be indicated by a distinct cloud or white precipitate.

In all these determinations, control samples of Types 302 or 304 are run in adjacent beakers, for comparison.

Nickel-containing Materials in Pulp- and Paper-Processing Machinery

INTERNATIONAL NICKEL CO., INC.: 'Practical Solutions for Metal Problems in Pulp and Paper Mills.'* *Published* 1951; 33 pp.

This brochure opens with a two-page diagram, illustrating pulp- and paper-making processes, as practised in a typical plant. This is followed by sections discussing, from an eminently practical standpoint, the nature of the corrosion problems encountered in the various parts of the plant, and the materials which may be used to overcome difficulties due to the severity of the conditions obtaining. The discussion includes reference to chemical pulping equipment; brown-stock washers, thickeners and filters; screening processes and equipment; stock- and white-water lines; bleached-pulp thickeners and washers; sizing, fillers and colours; refining of stock; paper- and board-machines and paper-machine rolls; plant used in caustic recovery, and in chemical recovery processes; pumping equipment. The many uses of nickel-containing materials, especially Monel, Inconel and nickel-clad steel. are demonstrated by a series of over 60 photographs illustrating typical equipment now in commercial use.

Copper-Nickel-Iron Condenser-Tube Alloys

G. L. BAILEY: 'Copper-Nickel-Iron Alloys Resistant to Sea Water Corrosion.'

Jnl. Inst. Metals, 1951, vol. 79, pp. 243-92; Advance Copy 1308; *Monthly Jnl.*, July, 1951.

This paper contains the most comprehensive report yet published on British research relating to condenser-tube materials, tracing development from the setting up of the Corrosion Research Committee of the Institute of Metals, in 1910, through to the evolution of the iron-modified alloys which have resulted from investigations carried out by the British Non-Ferrous Metals Research Association.

The report contains much detailed, but highly condensed, information, for which the original must be consulted. The following abstract gives only the scope of the paper, and a summary of the main conclusions.

The early history of researches by the Institute of Metals Corrosion Committee is reviewed, and reference is given to the eight reports published during its 20-year period of activity. Attention is also directed to later papers which have summarized the nature and extent of the corrosion occurring in cooling-water systems, and the relative resistance of various materials. As a background to the report of recent investigations, notes are given on the main types of attack to which reference is made in the paper:—impingement attack (or corrosion-erosion), deposit attack, and pitting. The conditions which give rise to each of these forms of attack are indicated, and a description is given of the types of test which have been devised (and used in the investigations reported) for determining the relative resistance of various materials to the differing forms of attack.

Following these introductory sections, the major part of the paper is concerned with a detailed account of the investigations carried out in the laboratories of the British Non-Ferrous Metals Research Association.

In the pre-war period a considerable amount of work was done on the effect of additions of iron on the corrosion-resistance of 70-30 cupro-nickel, and as a result of the evidence obtained on the beneficial influence of iron additions, the corrosion resistance of iron-containing nickel-copper alloys of lower nickel content was studied. The investigations comprised mainly tests of resistance to impingement attack in moving sea water containing air bubbles, and included observation of corrosion at shielded areas, under conditions of rapid water movement. These tests were supplemented by examination of resistance to attack under deposits in stagnant conditions. From the results of this work the conclusion was drawn that the lower-nickel alloys containing iron in percentage of 0·3 to 4 per cent. showed considerable promise of resistance to impingement attack. (Manganese was found to supplement the effect of iron, particularly at low iron contents, but its beneficial effects are of minor importance by comparison with the influence of iron.) Under conditions favouring deposit attack, however, alloys containing iron in the higher regions of the 0·3-4 per cent. range showed an undesirable tendency to pitting, and it was concluded that, having regard to pitting, deposit and impingement attack, the optimum iron content for general resistance to corrosion would be of the order of 0·5-1 per cent.

The extensive series of tests made on these iron-containing lower-nickel alloys (of which a lengthy report is given) indicated that optimum corrosion resistance in the low-nickel range was offered by the alloy containing nickel 10, iron 2, per cent. Results obtained on a 5 per cent. nickel, 1·5 per cent. iron alloy were nearly as good when the alloy was in the quenched condition, but this material showed greater deterioration than the higher-nickel alloy when annealed at 600°C. With 7·5 per cent. nickel and 1·7 per cent. iron excellent corrosion resistance was obtained, but the data available on this alloy are at present insufficient to enable accurate comparison to be made with the 5 and 10 per cent. nickel grades. Addition of 1·3-2 per cent. of iron to these alloys confers a degree of corrosion resistance of the order of that characteristic

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of 70-30 cupro-nickel containing iron 0·3-0·5 per cent. (Attention is drawn to the close correlation of the author's results with those reported by TRACY and HUNGERFORD (*Proc. Amer. Soc., Testing Materials*, 1945, vol. 45, pp. 591-612).

Closer study of the low-nickel alloys, and, in particular, the sensitivity of their corrosion-resisting properties to heat-treatment, showed that best results are secured by quenching from temperatures in the region of 850°-950°C. Annealing or slow cooling sensibly reduces corrosion-resistance, particularly in contaminated water: the effect is considered to be due to separation of a second solid solution richer in nickel and iron. The degree of lowering of corrosion-resistance cannot, however, be regarded as serious, since even in the annealed condition these low-nickel alloys are equal to 70-30 cupro-nickel of low iron content (0·04 per cent.). Subsidiary experiments in this part of the investigation covered a study of the influence of manganese and phosphorus contents on alloys of the type described. Within the limits of composition used, no evidence was obtained of any influence of either element, on the corrosion-resisting quality of the alloys.

In view of the importance of providing alloys for use in sea-water-carrying pipes in ships, an examination was made of the mechanical and working properties of the low-nickel iron-containing alloys. The materials proved to be readily workable, under both hot- and cold-working operations, provided that certain precautions are taken in heat-treatment. Optimum corrosion resistance is not compatible with hot workability, since breakdown of the corrosion-resistant structure which occurs on heating at 600°-700°C. develops a liability to cracking, but the corrosion-resistance of the alloys as usually manufactured in tube form is, in normal circumstances, not sufficiently below the optimum to warrant employment of the troublesome procedure which would be necessary to ensure the highest possible degree of corrosion resistance.

A tabular comparison of jet-test results on the 5 and 10 per cent. nickel iron-containing alloys, with standard condenser-tube materials, clearly demonstrates the outstanding qualities of the new materials.

Appendices to the paper contain reports on

(1) The Structure of Copper-Nickel-Iron Alloys.

(2) Mechanical and Working Properties of the Copper-Nickel-Iron Alloys (mainly on alloys containing 5 per cent. nickel with 1·1-1·8 per cent. iron, with some data on alloys of the 10 per cent. nickel, 2 per cent. iron type).

Corrigendum

Brazing of Nickel-containing Materials

Nickel Bulletin, 1951, vol. 24, No. 6, June, p. 128.
In first line of abstract for 'B.S. 1725' please read 'B.S. 1724.'

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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